Student Textbook page 7

Q1.

Chemical notation	Element	Atomic number (Z)	Mass number (A)	Number of protons	Number of neutrons
$^{11}_{5}B$	boron	5	11	5	6
$^{208}_{82}Pb$	lead	82	208	82	126
$^{184}_{74}W$	tungsten	74	184	74	110
$^{4}_{2}He$	helium	2	4	2	2
$^{239}_{94}Pu$	plutonium	94	239	94	145
$^{56}_{26}Fe$	iron	26	56	26	30
$^{209}_{83}Bi$	bismuth	83	209	83	126
$^{107}_{47}Ag$	silver	47	107	47	60*
$^{20}_{10}Ne$	neon	10	20	10	10
$^{108}_{47}Ag$	silver	47	108	47	61
$^{75}_{33}As$	arsenic	33	75	33	42
$^{80}_{35}Br$	bromine	35	80	35	45
$^{197}_{79}Au$	gold	79	197*	79	118
$^{119}_{50}Sn$	tin	50	119	50	69

*Please use these revised numbers.

Q2. (a) helium, neon, argon, krypton, xenon, radon

(b) beryllium, magnesium, calcium, strontium, barium, radium

(c) fluorine, chlorine, bromine, iodine, astatine

(d) lithium, sodium, potassium, rubidium, cesium, francium

Answers to Questions for Comprehension

Student Textbook page 13

Q3. (a) aluminium(III) oxide

(b) mercury(II) iodide

(c) sodium phosphide

(d) calcium bromide

Q4. (a) ZnO

(b) FeS

(c) MgI_2

(d) $CoCl_3$

Q5. (a) sulfur hexafluoride

(b) dinitrogen pentoxide

(c) phosphorus pentachloride

(d) carbon tetraflouride

Q6. (a) H_2O

(b) SO_3

(c) N_2O_4

(d) N_2O

Q7. (a) potassium phosphate

(b) ammonium chloride

(c) lithium perchlorate

(d) sodium hydrogen carbonate

Q8. (a) $KClO$

(b) $MgOOCCOO$

(c) $NaCN$

(d) $(NH_4)_2SO_4$

Student Textbook page 19

Q1. (a)

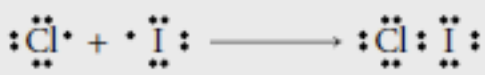
(b)

(c) A compound is not possible because both atoms need to lose electrons.

(d) Only a covalent (molecular) compound is possible because both atoms need to gain (or share) electrons.

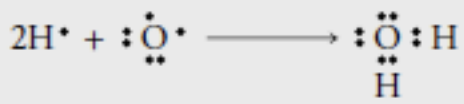
Q2. (a) A molecular compound will not form because neon has a full octet.

(b)



(c) A molecular compound will not form because lithium's electronegativity is too low.

(d)



Q3. The octet rule states that no more than eight electrons can exist in the outer energy level of any atom, and that when bonds form, atoms gain, lose, or share valence electrons in such a way that they create a filled outer energy level of electrons. It appears that this filled outermost energy level is especially stable.

Q4. 1. Draw the symbol for the nitrogen atom.

2. Determine the number of valence electrons in a nitrogen atom. (5)

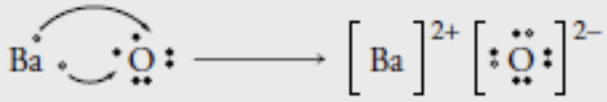
3. Begin on any of the four sides around the symbol, and place one dot on each side until all four sides have one dot.
4. Pair the last electron with an existing single.

Q5. A valence electron is an electron in the outermost energy level or shell of an atom.

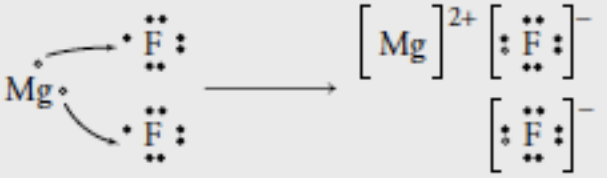
Student Textbook page 21

Q6. (a) KCl

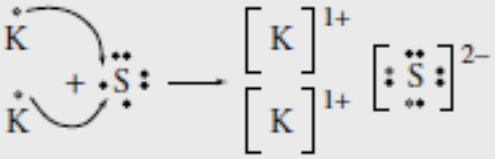
(b) BaO



(c) MgF_2



(d) K_2S



Q7. (a) ZnO

(b) FeS

(c) MgI_2

(d) $CoCl_3$

Student Textbook page 25

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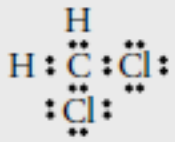
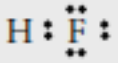
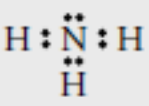
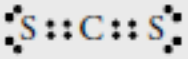
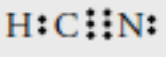
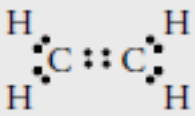
1. 

2. 

3. 

4. 

5. 

6. 

Student Textbook page 27

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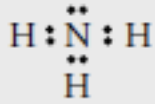
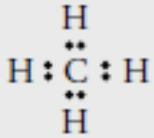
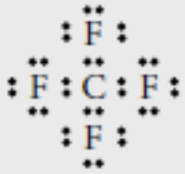
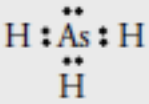
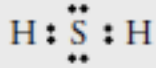
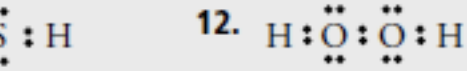
7. 

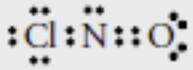
8. 

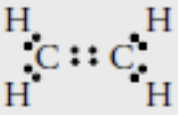
9. 

10. 

11. 

12. 

13. 

14. 

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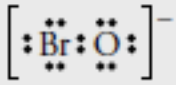
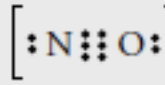
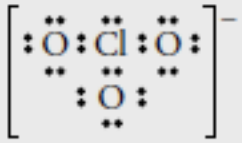
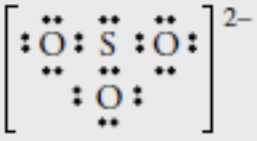
18. 

19. 

20. 

21. 

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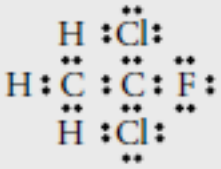

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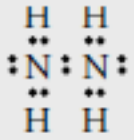

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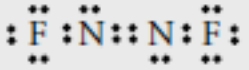

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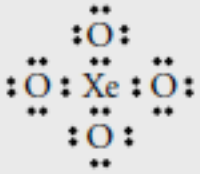
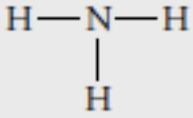


Student Textbook page 31

Q8.

a)



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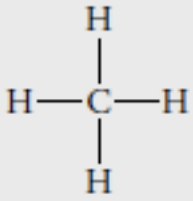
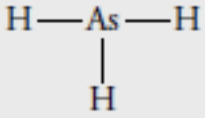


c)

d)



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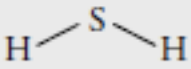

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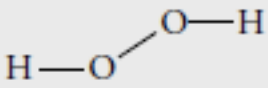

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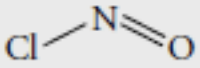

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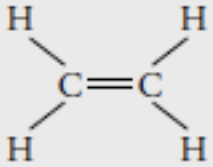

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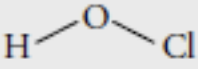


j)

Student Textbook page 34

Q9. (a) silicon dioxide

(b) cesium iodide

(c) sodium hydrogen phosphate

(d) dinitrogen pentoxide

(e) barium hydroxide

(f) nitrogen tribromide

(g) ammonium hydrogen phosphate

(h) hydrogen chlorate

(i) aluminium oxide

(j) magnesium nitrate

(k) potassium hypochlorite

(l) potassium permanganate

Student Textbook page 35

1. The noble gases are especially stable, and, with the exception of helium, each have eight valence electrons. This leads to the idea that when atoms have the same electron configuration as one of the noble gases, a stable octet, they will no longer react.

2. (a) Valence electrons are the electrons in the outermost energy level or shell of an atom.

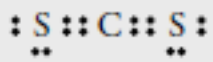
(b) A lone pair is a pair of unbonded valence electrons in an atom.

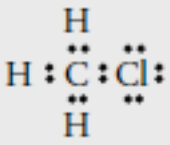
(c) An unpaired electron is a valence electron that has no partner to form a pair. It is available to participate in bonding.

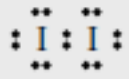
(d) An ionic bond is an electrostatic attraction between oppositely charged ions.

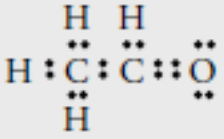
3. (a) 1 : 2 **(b)** 1 : 1 **(c)** 1 : 1 **(d)** 1 : 1

4. No dots signify that the atom has lost all of its valence electrons, and has become a positive ion. (Except in the case of hydrogen, the ion would still have electrons in filled lower energy levels.)

5. (a) 

(b) 

(c) 

(d) 

6 (a) The atoms contribute only 17 valence electrons, but the structure has 18.

or

The second carbon atom has 10 electrons surrounding it instead of eight.

(b) The hydrogen atom has eight electrons surrounding it instead of two.

(c) Both the oxygen atom and the carbon atom have 10 electrons surrounding them instead of eight.

or

The atoms only contribute 13 valence electrons, but the structure has 16.

7. (a) magnesium chloride **(b)** sodium oxide

(c) iron(III) chloride **(d)** copper(II) oxide

(e) zinc sulfide **(f)** aluminium bromide

8. (a) $FeCl_3$ **(b)** MgO **(c)** KBr

(d) Ca_3P_2 **(e)** MnS **(f)** BaI_2

9. (a) potassium chromate **(b)** ammonium nitrate

(c) sodium sulphate **(d)** strontium phosphate

(e) potassium nitrite **(f)** barium hypochlorite

10. **(a)** $NaHCO_3$ **(b)** $Na_2S_2O_3$

(c) $NaClO$ **(d)** $LiNO_2$

(e) $KMnO_4$ **(f)** NH_4Cl

11. **(a)** sulfur dioxide **(b)** carbon monoxide

(c) dinitrogen pentoxide **(d)** dichlorine monoxide

12. **(a)** H_2O **(b)** SO_3 **(c)** $SiCl_4$

13. **(a)** Atoms are represented by A, F, and G, since the number of electrons and protons are equal making a net charge of zero. Ions are represented by B, C, D, and E, since the number of electrons and protons are not equal.

(b) B^{3-}, C^{+}, D^{2+}, E^{-}

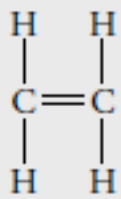
(c) A is B (boron), B is N^{3-} (nitride ion), C is K^{+} (potassium ion), D is Zn^{2+} (zinc ion), E is Br^{-} (bromide ion), F is B (boron, different isotope from A), G is F (fluorine).

14. **(a)** Potassium bromide is not a molecule, but an ionic compound. It would be appropriate to say "four formula units of potassium bromide."

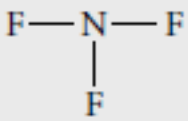
(b) Since the ion in this compound contains hydrogen, the name of the compound is sodium hydrogen sulfate.

(c) Potassium nitrate is KNO_3. This compound, KNO_2, is potassium nitrite.

15. **(a)**



(b)



(c)

Student Textbook page 41

Q10. (a) $\Delta EN = 1.43$, therefore the bond is polar covalent

(b) $\Delta EN = 0.40$, so the bond is slightly polar covalent

(c) $\Delta EN = 0$, so the bond is non-polar covalent

(d) $\Delta EN = 1.54$, so the bond is polar covalent

(e) $\Delta EN = 0.30$, so the bond is slightly polar covalent

(f) $\Delta EN = 3.05$, so the bond is mostly ionic

(g) $\Delta EN = 1.61$, so the bond is polar covalent

(h) $\Delta EN = 1.89$, so the bond is mostly ionic

Q11. (a) partial positive: carbon end; partial negative: fluorine end

(b) partial positive: nitrogen end; partial negative: oxygen end

(c) no partial positive or partial negative

(d) partial positive: copper end; partial negative: oxygen end

(e) partial positive: silicon end; partial negative: oxygen end

(f) partial positive: sodium end; partial negative: fluorine end

(g) partial positive: iron end; partial negative: oxygen end

(h) partial positive: manganese end; partial negative: oxygen end

Q12. (a) carbon bonded to sulfur ($\Delta EN = 0.03$), oxygen bonded to nitrogen ($\Delta EN = 0.40$), hydrogen bonded to chlorine ($\Delta EN = 0.96$), sodium bonded to chlorine ($\Delta EN = 2.23$).

(b) nitrogen bonded to nitrogen ($\Delta EN = 0$), carbon bonded to chlorine ($\Delta EN = 0.61$), phosphorus bonded to oxygen ($\Delta EN = 1.25$), magnesium bonded to chlorine ($\Delta EN = 1.85$).

Student Textbook page 42

1. Electronegativity is the relative measure of an atom's ability to attract the shared electrons in a chemical bond.
2. The electrostatic force is the mutual attraction between negative and positive charges. In ionic bonds, there is an attraction between positive and negative ions; in covalent bonds, there is an attractive force between the shared electrons and the positive nuclei of the atoms.
3. As you look across any period on the periodic table from left to right, electronegativity increases as the atomic number increases until you reach the noble gases.
4. As you look down any group (except the noble gases) on the periodic table, electronegativity decreases.
5. There is an inverse relationship between the size of an atom and its electronegativity. As the number of protons in the nucleus increases, the attractive force on the electrons increases, pulling them closer to the nucleus. The size of an atom determines how close bonding electrons can get to the nucleus. Therefore, size affects how strongly the positively charged nucleus can attract those electrons in the bond. As size decreases across the period, electronegativity increases. As size increases down a group, electronegativity decreases.
6. There is no clear distinction between bond types. Bond types are viewed as parts of a "bonding continuum" and cannot be rigidly categorized.

7. In order of increasing attraction:
   - **(a)** N and O, $\Delta EN = 0.40$
   - **(b)** H and Cl, $\Delta EN = 0.96$
   - **(c)** Mn and O, $\Delta EN = 1.89$
   - **(d)** Ca and Cl, $\Delta EN = 2.16$

8. **(a)** Mostly ionic bonds are formed between atoms whose ΔEN is between 1.7 and 3.3.

   (b) Polar covalent bonds are formed between atoms whose ΔEN lies between 0.5 and 1.7.

   (c) Non-polar covalent bonds are formed between atoms whose ΔEN is between 0 and 0.5.

9. Potassium and fluorine would form a non-polar bond.

10. **(a)** mostly ionic

    (b) non-polar covalent

    (c) non-polar covalent

    (d) mostly ionic

Student Textbook pages 44–45

1. Noble gases are never found bonded in nature, so they are very stable. Atoms of noble gases also have their outermost energy level filled, with eight electrons for all but helium. This leads to the conclusion that in bonding, atoms can become more stable by gaining, sharing, or losing electrons to achieve an outermost energy level of eight electrons like a noble gas. This is the octet rule.

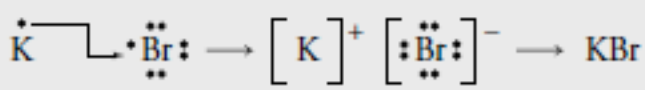
2. Hydrogen does not conform to the octet rule because its outermost energy level becomes filled with only two electrons. In order to achieve a filled outermost energy level, it needs to gain only one electron or share two. Helium also does not conform; it has two electrons in its outer shell.

3. An electron dot diagram is a model that shows the valence electrons of the atoms surrounding the chemical symbol of the atom. The electrons are often arranged in pairs, shared electrons are shown between atoms, and the diagram also demonstrates how electrons form octets in compounds.

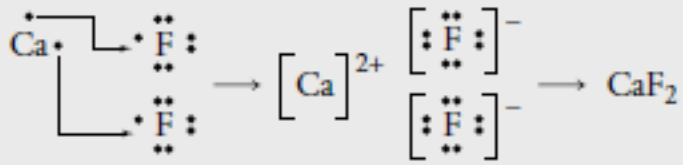
4. (a) $H\cdot$ **(b)** $\cdot\ddot{N}\cdot$

(c) $\cdot Ba\cdot$ **(d)** $:\ddot{I}\cdot$

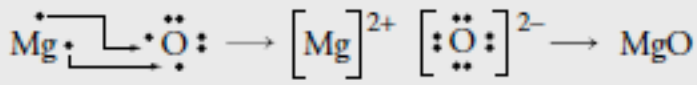
5. (a)



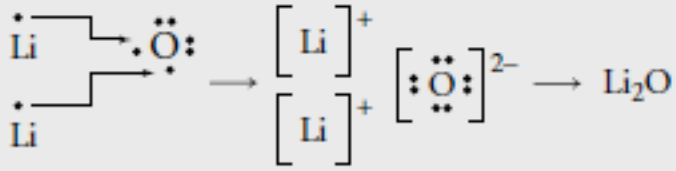
(b)



(c)



(d)



6. The number of electrons in non-metals that are involved in bonding corresponds to the number of single electrons in the electron dot diagram. Lone pairs are not involved in bonding.

7. (a) $\ddot{S}::C::\ddot{S}$

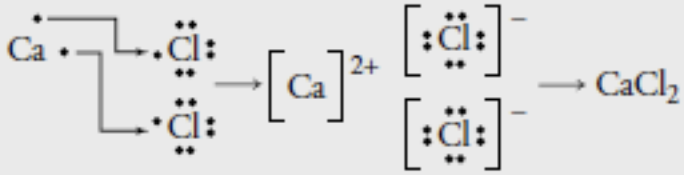
(b) $:\ddot{Br}:\ddot{O}:\ddot{Br}:$

(c) $:\ddot{Cl}:\ddot{F}:$

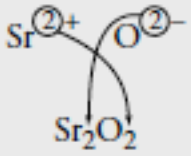
(d)

$$\begin{array}{c} :\ddot{F}: \\ :\ddot{F}:\ddot{N}:\ddot{F}: \end{array}$$

8.



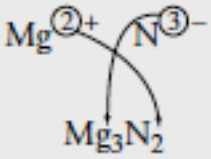
9. Strontium oxide



The lowest whole number ratio is 1:1 so the formula is:

SrO

Magnesium oxide



The lowest whole number ratio is 3:2 so the formula is:

Mg_3N_2

10. A lone pair is a pair of electrons in an atom's shell that are not involved in bonding. A bonding pair is a pair of electrons that are shared between two atoms to form a bond between the atoms.

11. Each oxygen atom contributes two electrons to form a double bond. In effect, the two oxygen atoms share four electrons, making a stable octet for each atom.

12. In a structural formula, one bonding line replaces the two dots of a bond in the Lewis structure. Two bonding lines replace the four dots of a double bond in a Lewis structure. Non-bonding (lone) electron pairs are not shown. Otherwise, the structure shown for the molecule remains the same.

13. Metallic bonds cannot be ionic since metals tend only to lose electrons, forming positive ions, so there are no negative ions with which to bond. If two metals shared all their valence electrons, there would still be less than eight in the outermost energy level, so the bonds cannot be covalent.

14. Valence electrons in metals are held loosely and are free to move from atom to atom. The electrostatic force between the positively charged metal ions and the cloud of negative electrons surrounding them create the metallic bonding. This is the free-electron model of metallic bonding.

15. **(a)** SnF_2 **(b)** $BaSO_4$ **(c)** HCN
(d) CsBr **(e)** $(NH_4)_2HPO_4$ **(f)** $NaIO_4$
(g) $KBrO_3$ **(i)** $Ca(ClO)_2$ **(j)** $Pb_3(PO_4)_2$
(h) NaCN

16. **(a)** hydrogen iodite **(b)** cesium fluoride
(c) sodium hydrogen sulfate **(d)** potassium dichromate
(e) potassium perchlorate **(f)** dinitrogen dichloride
(g) aluminium sulfate **(h)** iron(III) periodate

17. **(a)** ClF **(b)** P_2O_5
(c) SiS_2 **(d)** P_2Se_3

18. **(a)** carbon disulfide **(b)** iodine monochloride
(c) sulfur dioxide **(d)** dinitrogen trioxide
(e) phosphorus trichloride **(f)** selenium dibromide

19. Electronegativity applies to bonding or valence electrons.

20. Within a period, excluding noble gases, electronegativity increases from left to right. Down a group, electronegativity decreases from top to bottom.

21. (a) Li, La, Zn, Si, Br

(b) Cs, Y, Ga, P, Cl

22. In a non-polar bond, the sharing of electrons is equal between the atoms; in a polar bond, the sharing of electrons is unequal, with one atom attracting the electrons more strongly than the other.

23. (a) $\Delta EN = 1.79$, bond is ionic

(b) $\Delta EN = 1.35$, polar covalent

(c) $\Delta EN = 1.28$, polar covalent

(d) $\Delta EN = 0.40$, slightly polar covalent

24. (a) Mn and F, Mn and O, Mn and N

(b) Be and F, Be and Cl, Be and Br

(c) Ti and Cl; Fe and Cl; tie between Cu and Cl, and Hg and Cl; Ag and Cl

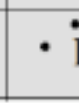
25. Since a polar covalent bond has some similarities with an ionic bond, and these similarities vary with the degree of polarity as measured by ΔEN, bonds form a continuum from non-polar covalent through polar covalent to ionic, with corresponding increases in percent ionic character and decreases in percent covalent character. Most bonds have some of each character.

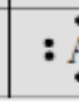
Answers to Applying Concepts Questions

26. Ensure that models demonstrate that in ionic compounds electrons are transferred and in molecular compounds electrons are shared. The idea that molecular compounds exist as discrete molecules but ionic compounds consist of innumerable formula units in a lattice would be a bonus. Assess and reward creativity, effectiveness, and artistic merit.

27. Since the elements Li, Be, B, C, N, O, F, and Ne are in order, the number of valence electrons corresponds to their position. Knowing that lithium is in the first place, it follows that lithium has one valence electron, beryllium has two, and the rest in order have three, four, five, six, seven, and eight.

28. (a)

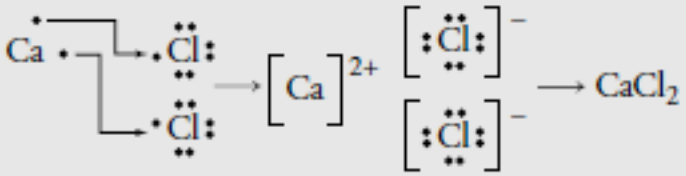
Group #	Example	Electron dot diagram	# valence electrons	# lone pairs	# unpaired electrons (number of bonds normally formed)	Nature of bonds formed (ionic, metallic, covalent)
1	Na, sodium		1	0	1	Ionic or metallic
2	Mg, magnesium		2	0	2	Ionic or metallic
13	Al, aluminium		3	0	3	Ionic or metallic
14	Si, silicon		4	0	4	Covalent
15	P, phosphorus		5	1	3	Covalent (nitrogen may form ionic bonds)

Group #	Example	Electron dot diagram	# valence electrons	# lone pairs	# unpaired electrons (number of bonds normally formed)	Nature of bonds formed (ionic, metallic, covalent)
16	S, sulfur		6	2	2	Ionic or covalent
17	Cl, chlorine		7	3	1	Ionic or covalent
18	Ar, argon		8	4	0	Usually does not form bonds

(b)
- The number of valence electrons increases from one to eight as you scan from Group 1 to Group 18.
- The number of electron pairs is zero for the first four groups and then increases from 1 to 4 for the last four groups.

- The number of unpaired electrons increases from 1 to 4 for the first four groups and then decreases from 3 to 0 for the last four groups.

29. An example might be as follows:



30. **(a)** C, carbon

(b) O, oxygen

(c) C, carbon

(d) N, nitrogen

(e) C, carbon

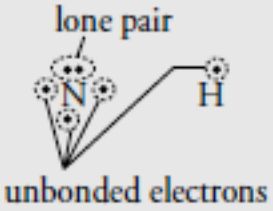
31. **(a)** Metallic bonds exist between atoms of iron in the sparkler.

(b) Covalent bonds exist between atoms of oxygen in air.

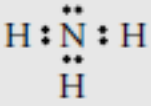
(c) Ionic bonds are formed between iron ions and oxide ions when the sparkler is burned.

32.

(a) & **(b)**



(c)



(d) The bonds formed between the hydrogen and nitrogen atoms are polar covalent bonds.

34. Borax contains sodium tetraborate decahydrate, which is ionic. Dishwasher detergent contains calcium carbonate and sodium silicate, which are both ionic. Envirodesign Kitchen Cleaner™ contains hydrogen anionic surfactants, so you could predict it will be molecular (anionic means "no ions"). Vinegar contains acetic acid, which is molecular. Most cleaners do not give the chemical contents, so students may have to predict from the cautions given or look at hair cleaning or personal care products, which often list ingredients. Epsom salt, $MgSO_4(s)$, is an ionic compound found in hard water. It is a solid crystal at room temperature and dissolves readily in water. It is made up of metallic magnesium ions joined to polyatomic ions composed of sulfur and oxygen. The bond must be strong because Epsom salt has a relatively high melting and boiling point and does not break down when stored for a long time. Coconut oil is a naturally occurring molecular compound made of carbon, hydrogen, and oxygen. It is a liquid at room temperature with a low melting temperature. The oil does break down over time, so the bonds are not as strong as those of Epsom salt.

35. A prediction could be "The greater the polarity of the bonds in a compound, the greater the solubility of the compound in water."